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ABSTRACT

The effectiveness of different types of computer terminals in programing learning is discussed with special reference to the experience of the Physics Computer Development Project. Experience with ten types of terminals including hardcopy terminals of several speeds, alphanumeric and graphic terminals is reviewed. Special consideration is given to the design of terminals, keyboard layout, use of characters and symbols, and the problem of terminal identification through software. Use of graphics and other optional features, using different computer speeds, and the differences between hard copy and soft copy are discussed. (RB)

TERMINALS FOR EDUCATION

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October 25, 1971

Although the Physics Computer Development Project has not been primarily concerned with testing of terminals with students, during the developing and using of physics teaching materials with large numbers of students we have had experience with many terminals, perhaps as many as ten types, including hardcopy terminals of several speeds, alphanumeric CRTs and graphic CRTs.

Much student experience has led us to be worried about the effect that the terminal has on students and concerned about the advantages and disadvantages of different terminals for varying educational uses. In a timeshared student environment the terminal <u>is</u> the computer to the student, because it is the terminal which the student sees and uses. Terminals do heavily influence teaching when computers are used in education and educational needs suggest aspects of terminal design and use that do not necessarily reflect current standards.

Many present terminals were designed for business use or for other applications predating the widespread use of computers. Hence it is not surprising that they are not ideal for teaching. It is my intent to discuss some of the important aspects of terminals with regard to their effectiveness in the learning environment.

Before getting into the main discussion, I would like to point out a linguistic problem not peculiar to education. All words have connotations, and it is easy to determine the general connotations of the word "terminal." Perhaps its most common everyday usage is to describe a "terminal illness." Even in

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other usages something ultimately final is often present in the way the word is used. I claim that "terminal" leads to problems when we use it with students because of these, perhaps unconscious, connotations. Unfortunately a good word to use in place of "terminal" is not apparent, and so I continue to use the word "terminal" in this paper in spite of my worries. Terminal is by far the most common word. Educational users sometimes employ the expression "student console," but that appears clumsy and unlikely to gain widespread popularity. With some terminals the word "typewriter" can be used, or perhaps "computer controlled typewriter," but this designation is inappropriate to other terminals. Perhaps the word "station" could be used, although it has religious and other connotations that may or may not be useful. My own linguistic talents are inadequate to the job of developing a new name here! But I do not think that the importance of this issue should be overlooked; affective and emotional issues play a large role in education, as we are gradually realizing.

Design Considerations

The first need I discuss is related to the issues of "name" just raised, in that it deals with factors which highly influence the attitudes students have toward terminals. Here, however, I am not talking about the name but rather about aspects of design, as understood in the sense of industrial design.

That industrial design has great influence on the educational process, in its broadest sense, has been realized by major manufacturers for a long period of time. Only a few manufacturers pursue the highest design standards. IBM is a shining example with its use of such superb designers as Elliot Noyes and Charles Eames in its products. But many terminal manufacturers consider design as only frosting on the cake in the final stages, and do not make full use of the knowledge of competent modern designers in making the terminal a more usable device for human beings.

Design in this sense goes far beyond the outward appearance of the terminal, although that is a factor. Even more important is the "feel" of using the terminal. Is it obvious how to turn the thing on and off? Is it apparent how to get on-line? Are switches that must be set often in the open or are they hidden under panels? What noises does the machine make--are these "friendly," helpful noises, or are they harsh, frightening noises? What does the bell sound like--does it knock the student out of his seat each time it rings? Is the layout of a keyboard convenient for someone used to typewriters but not computers? Does it abound with symbol names outside the student's experience which do not correspond to those he will find in the common student introductions to the computer? (The ASCII names for the control characters are particular offenders here--only devoted professionals can identify the official name for a control Y.) Are the buttons and lights useful to the student or do some of them simply entertain the engineer? Is the terminal visually attractive, pleasant to see?

We could go on with these questions but it should be clear as to what we mean by design considerations. We want the terminal to appeal to the student, to present a warm friendly appearance, to encourage its use. Many things enter into good design--the appearance, the sounds, the way it prints or displays information, the keyboard layout. These are not functional aspects of design, many of which will be discussed later, but aspects that most affect the user. Serious consideration should be given to these before producing terminals that encourage students to use the computer.

One aspect of design that needs further consideration is keyboard layout. With a proliferation of terminals many different keyboards have come into existence. Some of these are only minor variants on existing keyboards, but some are very different. In a project such as ours which uses many different types of terminals, we must learn a great versatility to react to the varying placement of keys. Our learning is often imperfect. Some human engineering is needed to improve this increasingly chaotic situation.

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Characters

Most terminals in common use with students today use the limited ASCII set, with capital letters, numbers, and a few necessary symbols. The larger ASCII set, including capitals, is sometimes available. The proposed double ASCII symbol set does not exist in any available terminal.

I believe that the symbol question for computers has not been considered in full detail, and that the implications go far beyond educational application. Man is a symbol-manipulating and symbol-using animal. No matter where we go, in what section of human endeavor, we find special symbols which are needed in that particular area. Thus suppose we consider a terminal in a college teaching environment, used by a succession of students. The first may be learning Russian, and so will need a symbol set that includes the Russian alphabet. The next student may be running programs in APL, so needs the symbols which are specialized to APL. The next student may be concerned with genetic simulation in a biological environment, and can very conveniently employ male and female symbols and the other special biological symbols. Perhaps the next student is a junior physics major, in electricity and magnetism; he needs differentiation and integration symbols and vector calculus operators. Finally the last student may be running a PL/1 program, and will require the symbols peculiar to that language.

Critical distinctions between symbols can often be overlooked by someone not active in the area concerned. To tell a person he cannot use the symbols he normally uses, but that he must use some more restricted set of symbols, is not only unwise pedagogically, but completely unnecessary. It is perfectly possible to design computer terminals which allow a natural use of symbols, more in keeping with their use in practice.

Two problems connected with symbols and terminals are the printing or displaying of symbols and the modification of keyboards to make it possible to use these symbols. Several terminals allow the printing or displaying of more than standard ASCII symbols.

Perhaps the most well-known, multi-character terminal is based on the Selectric typewriter, such as the IBM 2741. Here changing a symbol set means putting in a new type ball, a simple quick operation, so it is not surprising that Selectrics have been by far the most common terminals used with APL, with its special character set requirements. Designing a new ball with your own symbol set has a large one-time charge but the cost of additional balls is little. Another terminal which allows a change with similar functional results is the Memorex 1240, where the print chain can be removed and replaced, again in a short period of time. Print chains exist for full ASCII sets and APL. But a print chain is more expensive than a Selectric ball, and not quite as easy to replace.

Some CRT terminals are also available with extra character sets, usually implemented with switch-selectable ROMs. APL sets exist as options on the ARDS and COMPUTER graphic terminals.

It is not hard to see disadvantages with these existing approaches to additional characters. First, it is very difficult to add just a few characters, for a special use that does not depart very much from the standard one. One must go through the process of getting a new ball, a new print chain, a new ROM, etc. Second, is the terminal user to make the actual physical changes of the printing element? If you review the variety of students suggested above, then you may see we would expect a high attrition rate on balls or belts changed at the rapidity suggested!

In many cases the need for special characters is limited. Only a few "variable" characters may be needed beyond the standard symbols, but this need may be changing during program execution. It seems that the most rational approach for adding a few characters is to allow the selection of characters to be at least partially under program control. In many display terminals, and in the thermal printing terminals, characters are created by 5 x 7 or 7 x 9 dot matrix patterns. Hence to define a character means

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to select the right dots. It is a relatively simple piece of engineering to allow the program to instruct the terminal about a particular variable character, telling it what combination of dots are to be "turned on" for a special character.

What variable characters were specified could change during a session. At the monitor or executive level of the system the student might have the option of picking characters appropriate to whatever job he was engaged in. If he were going to enter a file through the editor, this would probably be a necessary choice, because that file might be a section of Yugoslavian text, a FORTRAN program, or some other file with special symbol requirements. Processors like PL/1 or APL would set the character sets internally in the program, as would teaching dialogs with particular character needs. So in addition to hardware changes in the terminal, software additions would be needed in the timesharing system to implement variable characters.

So far we have discussed only one aspect of this problem, the displaying of characters. But the student also needs to be able to <u>enter</u> these various characters in a natural way. Here the existing resolutions have often been most unsatisfactory. APL terminals often have special keyboards, making them useful for use in APL, but difficult to use when one goes back to a standard ASCII format. In some cases keys have been engraved with both sets of symbols, but this can rapidly become confusing; I have little sympathy for a keyboard recently displayed showing the extended ASCII set, about 200 characters, all engraved on the same keyboard. I think this will be very confusing to the user, particularly the novice student, and will serve to drive him away from computers. Furthermore, as we go to more and more varied character sets, we cannot engrave everything on the keys; the terminal manufacturer cannot foretell all the possible uses.

The simplest solution to the keyboard problem, already used in the Harvard TAC project, is to use plastic overlays fitting over

the keys with character identification on them. This requires keyboards more widely spaced than a standard typewriter keyboard, and so may lead to user difficulties. These plastic overlays could be printed with standard symbol sets, but blanks could be available to allow specialized uses. They are inexpensive so having students change one from a collection at the terminal would involve no great losses even if they were damaged.

The number of complete changes of symbol sets as represented by the change between APL and a standard ASCII set will probably be limited. In most cases the number of specialized symbols needed in a particular application will probably be small. Thus work in any language which uses the Latin alphabet involves only a few additional marks such as the diacritical marks. Here it is possible to take care of many variable symbol needs by having a special small side keyboard, perhaps using small plastic overlays. How many keys required on this keyboard is open to question. I would think that for the vast majority of needs a 3 by 3 arrangement with nine keys would be satisfactory, and I would probably even be willing to use less; the program can change the characters assigned to these particular keys, and let the user know this is happening. Some terminals already have such a side keyboard, duplicating numbers, and the cost of keyboards is almost trivial.

I can envision more elaborate solutions where the computer has control of what characters are "displayed" on each key. But these may be technically or financially infeasible at present. Generally the handling of the keyboard is, while in a sense more trivial, a more difficult issue than the displaying of characters.

It should be realized that I am using symbols in a generalized sense. Sometimes a symbol has different meaning because of its positioning with regard to other symbols; these positioning operations should be allowable ones within the extended character options. The most obvious of these is perhaps the subscript and superscript, universally used in scientific and mathematical notations, but, outside of the Plato Project, nonexistent on computer

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terminals. We should be able to display information having subscripts and superscripts to students, and they should be able to enter such in a natural way. So "subscript" and "superscript" would have to be a character in the sense used here.

The ability to shape more characters has a consequence in terms of the mechanisms for character production. The 5 by 7 dot matrix for characters has severe limitations if we are distinguishing between a great variety of characters; so the 5 by 7 matrix will be inadequate with extended character sets. Many terminals use it because of cost savings over a larger dot matrix. We can recognize letters, numbers and a few special symbols with the 5 by 7 matrix, but as we increase the number of characters they become more and more difficult to portray accurately in such a matrix. Thus larger character matrices, or curvilinear generators, will be necessary with larger character set options.

Terminal Identification

For a while "terminal" meant "Model 33 Teletype," or, perhaps if you are an IBM user, a 2741. The past few years has seen an enormous proliferation of terminals. Many are sold as "pluggable" replaceables for the Model 33 or the 2741, but many carry out functions impossible on earlier terminals.

The user quickly realizes, in spite of assurances from vendors, that all terminals have unique properties which affect both usage and basic system programming. Consider several examples. Some of the newer hardcopy terminals, discussed further in a later section, run at higher printing speeds than the Model 33, but otherwise are similar. The vendors often sell them as 33 replacements. But when you use these terminals, you discover that problems exist with currently available software, which assumes it is dealing with a Model 33; these problems differ from terminal to terminal. To illustrate, consider first the Execuport or the Texas Instrument 720, both very pleasant terminals with a printing head which moves across the page. On receiving a carriage return line feed combination, the printhead must get back to the beginning of the

line before the next character is sent, because no internal buffering is available. It succeeds in doing this in time at 100 baud but at 300 baud it does not succeed, even though it is a very light element. Hence the software must have a built-in delay after a carriage return, either sending out dummy characters, or in some way generating a delay. Otherwise for long lines some characters will be lost at the beginning of the line. On the other hand, the Memorex 1240, operating at similar speeds, has exactly the opposite problem. No physical carriage return is necessary, as the belt printer covers the entire page. Timing considerations on the belt require that it be in a certain position at the beginning of a line. If the line is too short, it does not have enough time during the carriage return to get back to this position. So lines that are too short, where "too" depends on the printing speed, will not come out looking right unless the software adapts to the situation, providing delays on short lines.

With graphic terminals, to be discussed later, the situation becomes even more drastic. First it is essential that the computer know whether it is dealing with a graphic terminal or not. It does it no good to attempt to draw pictures on the teletype! However, to identify the terminal as graphic is not sufficient. Most existing graphic terminals have different code requirements for drawing pictures. That is the basic graphic data, usually a 10-bit X and a 10-bit Y, is conveyed to the terminal in different ways. Data that will correctly drive our ARDS 100 will produce garbage on our Tektronix 4002, and vice versa. The computer must not only know that it is dealing with a graphic terminal, but must know precisely which graphic terminal.

I hope by this time I have convinced the reader that, as the number of terminals becomes greater and greater, if we are to be flexible, the software must have knowledge of the type of terminal being used. I will discuss two solutions to this problem, one rather primitive and a second more reasonable from a long-range point of view.

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The first identification procedure we already use with our graphic terminals. Our graphic programs will run on either terminal, but the computer (i.e., the program) must know which terminal is in use. It follows the simpleminded way of asking the student at the start of the program. This I regard as an acceptable interim solution but, as the number of terminals gets greater, not the best long-range solution. The user must be able to identify the type of terminal he is working on, usually displayed in letters on the terminal. We suggest the options allowable, to restrict his choice, and we just do not proceed until one of these is typed. A similar possibility suggested in a conversation with Ed Adams of IBM is to have an identification number on each terminal, and ask the student to type that number. However this would have problems for students accessing the computer through telephone lines with terminals not normally used on the system.

A satisfactory long-range solution requires that terminals identify themselves to the computer. Many engineering possibilities exist. One would be to have the terminal send out a character, or a sequence of characters, before logon; another possibility is to send the identifying information only at the request of the computer, through some special control character or other sequence. By agreement each terminal could be assigned a particular code; this could take into account, by having enough characters, a large number of possible terminals. This information would need to be accessible both to the communications routines in the timesharing monitor and also to user programs. Perhaps the political aspects would lead to more difficulties than the simple engineering required, because agreement would be essential on the part of many different vendors.

The software problems will be considerable, leading to major changes in software systems for timesharing. Some software systems are beginning to realize that different terminals can be using the system, and have system calls which allow programs to specify terminal types. But this is done only on a limited basis. Many systems can be modified for different terminals

only with diffitulty. The monitor needs to be written in a very flexible way, so that as new terminals are developed it is relatively easy to make changes to allow for different types. But my primary concern in this discussion is not with software, so I will not pursue this direction further.

Graphics

Graphic terminals have been mentioned a number of times. In computer educational applications graphics will be extremely important in the future, so a full consideration of terminals for education must comment on the educational advantages of drawing pictures for students, and, in some situations, being able to draw pictures to the computer. Our experience is still limited, particularly with large numbers of students, but is extremely encouraging.

At least three systems providing graphics have had some educational use, the Plato system, the Culler-Fried system, and the Oettinger TAC system.

One of the best arguments for graphics in education is to note how frequently people try to imitate graphics on unsuitable terminals. Thus plotting in crude fashion on teletypes is common, often accompanied with apologies to the student. Tables of numbers are only one way of viewing computer output from computational programs. Often to be able to see the particle move, or to see how the function looks, is of more critical importance educationally than the numerical values. So people have often strived, even with limited means, to overcome limitations and exhibit the results graphically.

I will not argue further the importance of graphics in education, but will assume that you are already convinced that drawing pictures is of use. I mention one more aspect: Did you ever see a textbook without illustrations? Educational terminal designers should look carefully at graphic possibilities.

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"Graphics" covers a number of things. First there is CRT graphics, as exemplified currently in such terminals as ARDS 100 and Tektronix 4002; variants exist depending on ease of erasing and other factors. Second, hardcopy graphics is exemplified in older devices such as the Calcomp and the newer inexpensive devices based on laboratory XY plotters. And finally, recent printing devices allow you to take CRT graphics and, usually by electrostatic means, translate into hardcopy. The general issue of hardcopy has implications both for graphic and nongraphic educational terminals, and will be discussed later.

Graphic input is just coming into use in the educational environment. Here again educational advantages can be seen, but the problems will probably be considerable. At present few timesharing systems can handle graphic input information, particularly when rapidly generated. Hardware has become relatively inexpensive; joy sticks cost little, and XY tablet-like devices can be purchased for about $2,000. For the moment it would appear that input graphics is a needed option, and one that should be accessible through software, but not an option required on every terminal.

One encouraging feature of graphics at the moment, from the user point of view, is the intense competition of several competing technologies. The net result is that graphic prices have declined and show signs of continuing to do so. Thus the new Tektronix terminal, the 4010, costs about half of what the previous similar terminal cost.

Speeds

One aspect of recent terminal proliferation has been that several speeds are available, either for hardwire or phone connections. For hardwire the rate depends on line capacities. For phone lines, up to 300 baud is possible with most couplers; some couplers and modems allow terminals with higher baud rates, but at considerable cost.

Most hardcopy terminals still run at 110 baud (since most are teletypes). However, a teletype user displaying much information quickly learns that the machine types at speeds slower than he can read. For educational uses this is devastating. With all this modern technology we do not print materials as fast as the student can read! The situation is entirely different with 300 baud. While some can read faster than this, for the vast majority of users 300 baud is a comfortable reading speed; the student does not feel that he is waiting for the slow computer. It seems to me that the argument is strong that any terminal displaying alphanumeric information, either hardcopy or graphic, should be operating at at least 300 baud.

On the other hand, I am not impressed, for many educational purposes, with terminals which operate alphanumerically much faster than 300 baud. While occasionally situations arise where large amounts of material are needed in a hurry for later reading, this is not typical. Usually we want students to look at material while being printed. For large printouts most systems allow the student to resort to the line printer, a more reasonable way of getting extensive output.

Hence I see little necessity to deliver alphanumeric information at rates like 1200 or 2400 baud, for the majority of educational uses. Speed often has distinct disadvantages. The software may not be sophisticated enough, given that currently it does not "know" the terminal type, to allow for terminal limitations. Thus on the Irvine Datapoints, for large displays at 1200 baud the print is rolling off the top of the screen before the student has a chance to read it! Reading is unpleasant, and in some situations impossible, because the lines keep moving up. This can be handled by software, by stopping occasionally, but only if the computer can distinguish what terminal it is handling. On present systems, where the terminal does not identify itself, 1200 baud can have as many handicaps as it has advantages, and leads to students looking over and over again at the same files trying to glimpse what is in them, wasteful of both system and human resources.

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So I consider 300 baud to be a good speed for alphanumeric information, and I believe that either slower or much faster than this leads to problems. I have no strong objection to 600 baud. The "faster" problems may eventually be solved by terminal identification and sophisticated software, so the situation may change then.

An important consideration educationally is the speed at which pictures can be drawn. Operating at 300 or 1200 baud, current graphic CRT terminals draw pictures at the rate a person would draw them in a freehand sketch. This is satisfactory for many applications; in a few situations it would be desirable to have a faster graphic rate. Since 1200 baud is about as fast as is currently feasible to transmit over existing telephone lines, it seems a good compromise for educational purposes.

However more efficient graphic modes, allowing the sending out of the information in compressed form, would be desirable for some applications. Most graphic terminals do have a range of modes for graphic information, but further consideration needs to be given to faster graphic output. Some terminals implement curved lines, in addition to straight lines, in the hardware and this could, if handled effectively, lead to sending less information and so drawing pictures faster.

Hardcopy versus Softcopy

Older terminals were almost inevitably hardcopy devices. Recent years have brought a vogue for CRTs, both alphanumeric and graphic, which do not leave the students with pieces of paper to walk away with. I propose to comment, based on our experience at Irvine in the Physics Computer Development Project, on relative advantages of hardcopy and softcopy for student use.

It has been argued that the student's dependence on hardcopy, clearly visible at the current time with student use, is simply a factor of current conditioning, and that we will be moving eventually toward a paperless society with only softcopy available. While I can see this as a possible future occurrence, present

planning for educational use must provide the possibilities of hardcopy, both for alphanumerics and graphics, for students in some situations.

At Irvine student terminals are mostly Datapoints or Model 33s. Students often start using Datapoints; they are recommended in the introductory programming course, they are better designed, and they are more exotic with their much faster (300 and 1200 baud) writing speeds. But the teacher often finds students reverting to teletypes as the course progresses, because they find a need for hardcopy when they work at home or in preparing problem sets. Thus they are willing to go back to unpleasant terminals to acquire such copy.

Even with dialogs hardcopy has teaching uses. In complicated student-computer conversations using hardcopy terminals we often see students looking back over earlier parts of the dialog in deciding how to respond to a current question. If we plan carefully what to put on each CRT presentation, we can assure that the relevant information is available, but only at the cost of restricting the student's freedom by telling him, indirectly, what is relevant. So hardcopy allows more effective dialogs.

The hardcopy-softcopy issue cannot be resolved by specifying one or the other. Both have their uses in educational environments, in different ways. Clearly the students do not need to get everything on paper, as seen by the full wastebaskets in hardcopy terminal rooms. On the other hand, it is important to have some things on paper. I believe the rational approach is to provide selective hardcopy for students, controllable by them.

This can be done in a number of ways. Optional hardcopy can be available at the individual terminal; a number of hardcopy devices with CRT terminals are available. These allow the students to obtain copies of what is currently on the screen by pressing a button. With graphic terminals, this might be both alphanumeric and graphic information. These units are at present expensive,

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In a school where terminals are likely to be grouped a reasonable solution is to have a number of terminals, alphanumeric and/or graphic, sharing one hardcopy device, a device fast enough to service all terminals in the room. Thus we might envision a fast electrostatic printer serving six graphic terminals. Output would have to be identified with regard to the individual student. As suggested the question of what hardcopy was obtained would be under the control of the student. He could ask for hardcopy, either by turning off and on the hardcopy option or by asking that what is currently on the screen be made available in printed form. Some software development would be needed in addition to the hardware.

Where graphics are not being used, I think the arguments are strong for providing hardcopy at every terminal, even at the waste of some paper, at the present time. The 300 baud thermal printers seem to be the best present compromise. Access to the line printer from terminals covers some, but not all, of the needs.

Optional Features

Terminals offer a great variety of optional features. Some are concerned with the way the terminal operates, while others are "attachments" which increase the functions of the terminal.

Educational environments have used terminals with many optional attachments and discussed even more. These include slides, audio output, film output, video output, microfilm or microfische retrieval units, etc. These options should continue to be available, perhaps through general purpose interfacing units built into the terminal. Further terminals should make it easy for the user to adapt options peculiar to his own needs. Thus we have adapted several terminals to operate a single frame movie camera, through sending of the control signals to the terminal. This turns out

to be easy in some cases, and relatively difficult in others. Terminals should be designed so that such interfacing is simple; any control signal should be available externally for the user. The art of digital design is well known, and in many cases, with a universal interface allowing one to get at the hardware, it would be possible for the user to build his own special purpose interface units. Computer design should allow this possibility.

However, I do not believe that we should be <u>forced</u> to buy any of these options. We have relatively little experience educationally in using them, and while I believe we should develop materials that exploit each possibility, the educational case for their usefulness still needs to be made.

Another optional feature, the tape cassette, is more difficult to evaluate. On the one hand, such a cassette could take over many of the functions of hardcopy, allowing students to review previous work, and on the other, it could relieve the storage burden in the central processor. But so far most of these units are too costly for widespread use, and some have very little student experience upon which to base a reasonable decision. Furthermore the engineering details of existing units do not seem adapted to educational usage.

Many other functional options are useless educationally, at present. The local editing facilities in some CRT terminals are a prime example. Existing timesharing systems almost always provide powerful on line editing, so having this at the terminal is only a duplication; perhaps if software developers leave this feature to hardware, we could be more enthusiastic about terminal editing. However, the "roll-down" feature on a few alphanumeric CRT terminals, allowing the student to review previous work during the session, is useful in overcoming some of the limitations imposed by the lack of hardcopy.

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Costs

If terminals are to be widely used in learning, cost is an important factor. This is even more the case when we think of moving outside the standard school or university enrivonment, having educational terminals in homes, shops, etc. Cost is a factor and will continue to be.

Besides this, only a little can be said. For certain environments we should get away from the philosophy of the completely self-contained unit and learn to timeshare some of the terminal hardware. Almost all terminals, for example, have character generators used far less than their full capacity; probably a single character generator could service a number of terminals. Other electronic components might be shared between terminals in building clusters of terminals, and this might lead to cost reduction. Most design has assumed a self-contained terminal, but this does not seem to be the only possibility.

Another recent development bears some promise for cost reduction, the interfacing of computers with existing equipment such as television sets and typewriters. Almost all homes have television sets, and many have typewriters. Terminals have seldom been built with the full facilities in modern mass production, so any way we can begin to use these facilities will be advantageous to us as educational users.